



An annotated checklist of vascular plants in and around two major high-altitude wetlands of Lahaul-Spiti, Himachal Pradesh, India

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Abstract

We document for the first time the diversity of vascular plants of Chandra Tal and Suraj Tal, two high-altitude wetlands (HAWs) spanning the cold desert region of Lahaul-Spiti, showing the occurrence of 188 species and one variety distributed among 97 genera and 29 families. Only one species, *Ephedra intermedia* Schrenk & C.A. Mey. is a gymnosperm, and the other 187 species are angiosperms. Of the angiosperms, Asteraceae is the dominant family, consisting of 27 species and one variety in 17 genera. Among the species, six are classified as threatened, 17 species are native, and two species (*Eritrichium nanum* (L.) Gaudin and *Ranunculus trivedii* Aswal & Mehrotra) are endemic to the Himalayan region. We provide baseline data for future research on the floristic diversity of two major HAWs of Lahaul-Spiti. We also highlight the importance of HAWs for the conservation of species.

Keywords

Chandra Tal, cold desert, floristic diversity, Suraj Tal, Trans-Himalaya

Academic editor: Arjun Prasad Tiwari | Received 26 April 2021 | Accepted 29 November 2021 | Published 16 December 2021

Citation: Dey D, Bhojak P, Chandra Sekar K, Arya D (2021) An annotated checklist of vascular plants in and around two major high-altitude wetlands of Lahaul-Spiti, Himachal Pradesh, India. Check List 17 (6): 1715–1730. <https://doi.org/10.15560/17.6.1715>

Introduction

High-altitude wetlands (HAWs) have been defined as “Areas of swamp, marsh, meadow, fen, peat-land or water bodies located at or above an elevation of 2500 m with an area equal to or greater than five hectares, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or saline” (Anonymous 2010). The Himalayas are home to some of the world’s largest and most spectacular glaciers (Brun et al. 2017), and the meltwater from these glaciers and seasonal

snow recharges HAWs. These wetlands are an important component in the hydrological regimes of mighty rivers like the Indus, Chandra, and Bhaga, among others.

Geographically, Lahaul-Spiti is the largest district in Himachal Pradesh, covering an area of about 13,883 km², and part of Indian cold desert in the north-western Himalaya. This region is remarkable for its high-altitude wetlands and lakes which have high biodiversity potential and which are fed by melt water.

Many studies have been carried out on the floristic diversity (Rau 1960; Nair 1964; Kapahi and Sarin 1979; Koelz 1979; Bhattacharyya and Uniyal 1982; Joshi 2003; Sharma and Samant 2016; Negi et al. 2019) or ethnobotany and resource use in Lahaul-Spiti (Kala 2003, 2006; Samant et al. 2007; Singh et al. 2007; Singh et al. 2009; Rana and Samant 2011). The systematics and taxonomic works in the Lahaul-Spiti region include the publications of Chowdhery and Wadhwa (1984), Aswal and Mehrotra (1994), Murti (2001), Chandra Sekar and Srivastava (2009), and Srivastava and Shukla (2015).

HAWs are one of the most unique as well as the most vulnerable ecosystems in the Himalayans and are very sensitive to global climate change and anthropogenic activities (Schmidt and Psenner 1992). The Space Research Organization recorded 271 HAWs with an area of 575 ha in Himachal Pradesh (Anonymous 2009). These wetlands are important to the people living in this region because they provide livelihood and are considered sacred. But very little information is available about HAWs due to the remoteness and harsh climatic conditions of the region. Any change to the dynamics of these wetlands can have a direct effect on biodiversity. A floristic diversity study is prerequisite and essential in achieving the targets of conservation and management in any ecosystem. Despite enormous biodiversity, very few floristic assessments of high-altitude wetlands in Indian Himalayan Region exist (Rawat and Adhikari 2005; Chandra Sekar and Rawat 2011). Here, we document and assess the diversity of vascular plants of Chandra Tal and Suraj Tal. We also analyse the composition of endemic and threatened elements for their conservation and management.

Study Area

Our study was carried out in and around Chandra Tal and Suraj Tal, which are in the cold desert region of Lahaul-Spiti, Himachal Pradesh, India (Fig. 1). Both wetlands are the part of Cold Desert Biosphere Reserve (CDBR), in Indian Trans-Himalaya (Samant et al. 2012). Chandra Tal is located at 32°28.552'N, 077°37.054'E at an elevation of about 4300 m; it is about 1750 m long, 500 m wide and 5 km in circumference (Sangewar 2012). It is a tourist destination for trekkers and campers and the source of the Chandra River. Chandra Tal is a wetland of international importance (a Ramsar site) and a part of Chandratat Wildlife Sanctuary which forms the core zone of CDBR (Fig. 2). Due to the presence of nutritive grass, the wetland also is a grazing ground for livestock. Suraj Tal is located at 32°45.749'N, 077°23.957'E and is just below the Bara-lacha-la pass at an altitude of about 4800 m. Originating from Suraj Tal is the Bhaga, river which meets the Chandra River downstream at Tandi to form the Chandrabhaga River. We categorized the habitats at our study areas as wet and marshy, moist, dry and rocky, or boulder. The map was produced in ArcGIS v. 10.5.

Methods

We conducted extensive and intensive field surveys in and around our two study sites during June to August from 2016 to 2019. Plant specimens were collected and preserved following the methods of Jain and Rao (1977) and housed in the herbarium of the G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora (GBP). The collected specimens were identified by comparing them with published floras of Himachal Pradesh (Chowdhery and Wadhwa 1984; Aswal and Mehrotra 1994; Murti 2001; Chandra Sekar and Srivastava 2009) and confirmed with specimens preserved in the Botanical Survey of India, Dehradun (BSD), Central National Herbarium (CAL), and Forest Research Institute, Dehradun (DD). Conservation Assessment and Management Prioritisation (CAMP) and International Union for Conservation of Nature (IUCN), and relevant published literature were used for determining threat status of species (Ved et al. 2003; Mehta et al. 2020; IUCN 2021). We consulted published works for determining endemism and native status of species in the Indian Himalayan region (Dhar and Samant 1993; Samant et al. 1998; Murti 2001; Singh et al. 2015; Srivastava and Shukla 2015). The habit and habitat of each species were recorded from our field observations, as well as herbarium and literature records. The Angiosperm Phylogeny Group (APG IV) system of classification was followed for arrangement of families (Chase et al. 2016). For nomenclature, Plants of the World Online (POWO) was followed. We provide taxonomic notes and a brief description for each of the threatened species in our list.

Results

We recorded 188 species and one variety belonging to 97 genera and 29 families (Table 1). Of the 188 species, one (*Ephedra intermedia*) is a gymnosperm. All other species are angiosperms (Figs. 3–6). Among the recorded threatened species, *Aconitum violaceum* (IUCN Red List 2021), *Rheum spiciforme*, and *Rhodiola heterodonta* are Vulnerable, *Arnebia euchroma* and *Saussurea gossypiphora* are Critically Endangered, and *Papaver guilelmi-waldemarii* is Endangered (Ved et al. 2003).

Threatened species

Asteraceae

Saussurea gossypiphora D. Don

Kasturi Kamal, Snowball Plant

Material examined. INDIA – Himachal Pradesh • A rare species occurring on alpine slopes, Lahaul-Spiti district, Suraj Tal; 32°45.728'N, 077°23.847'E; alt. 4624 m; 20.07.2016; DD & PB 4188, 4190 (GBP).

Identification. Stem 10–30 cm high, covered with long grey or white woolly hairs. Leaves linear, sessile. Heads

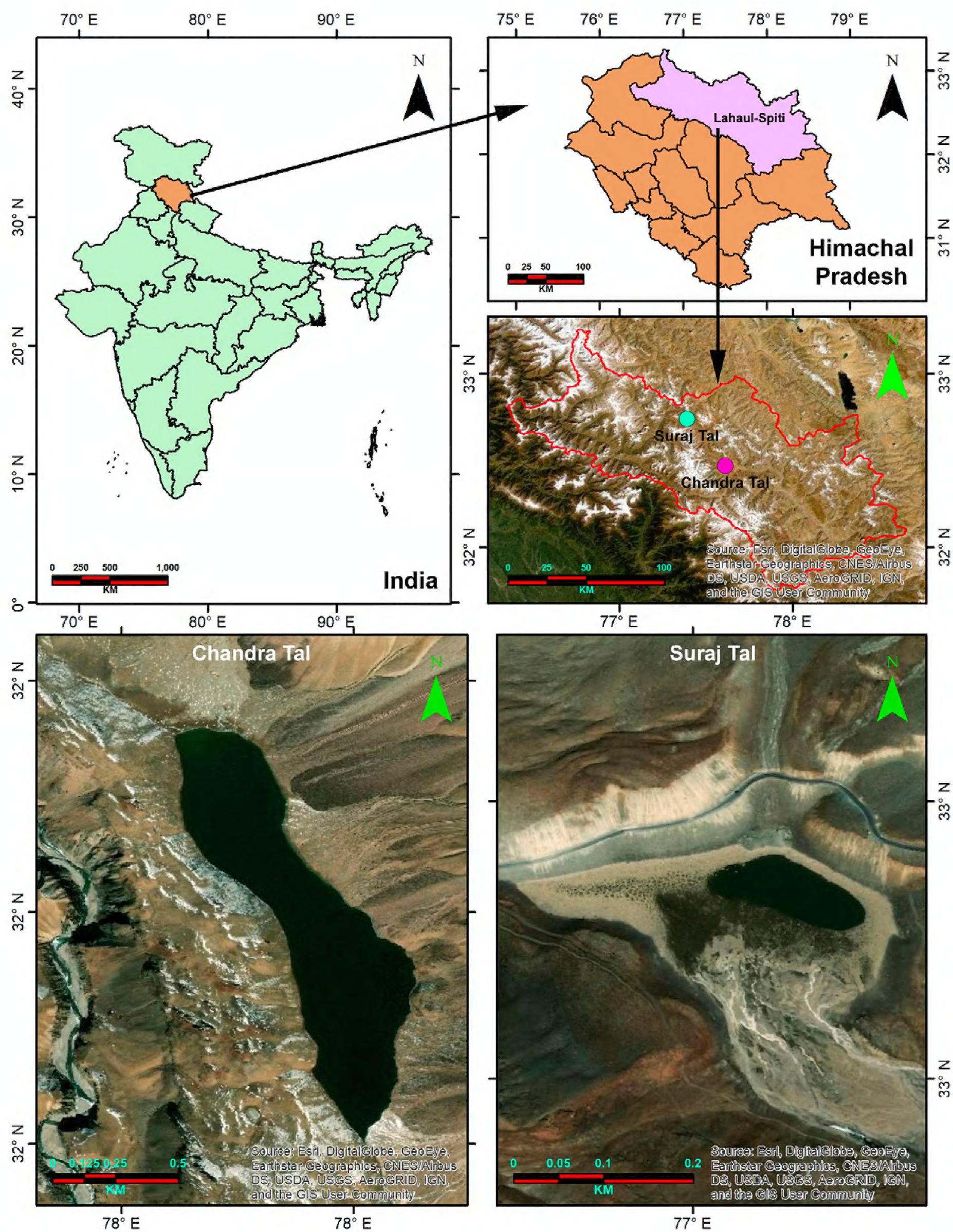


Figure 1. Study area map of two major (Chandra Tal and Suraj Tal) high-altitude wetlands of Lahaul-Spiti.



Figure 2. Habitat of Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti. **A–C.** Site view of Chandra Tal. **D.** Base camp at Chandra Tal. **E, F.** Site view of Suraj Tal. **G.** Base camp at Suraj Tal. **H.** Field survey and collection.

Table 1. Floristic diversity in and around Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti, Himachal Pradesh. Abbreviations: Occurrence: “+” = Present in the valley; Habit: Gr = Grass, H = Herb, Ru = Rush, Sh = Shrub, Se = Sedge; Nativity: ** = Native to Himalayan region; Habitat: DRS = Dry rocky slopes, DR = Dry rocky, SS = Sandy slopes, MOR = Moist rocky, MGS = Moist, grassy stream banks, RB = River banks, MS = Moist slopes, MSS = Moist sandy slopes, MR = Moist river beds/bank, DGR = Dry grass slopes, DGM = Dry glacial moraines, DS = Dry slopes, DSS = Dry sandy slopes, MM = Moist meadow, MGR = Marshy grass slopes, MGM = Moist glacial moraines, GM = Glacial moraines, MST = Moist stony slopes, MSH = Moist shady slopes, DBS = Dry bouldary slopes, MAS = Marshy slopes, MBS = Moist bouldary slopes, MSW = Marshy stagnant water, DGS = Dry glacial slopes, DST = Dry stony slopes, MME = Moist meadow, MAP = Moist alpine passes, DRC = Dry rocky crevices, GM = Grassy meadow, MG = Moist grassy meadows, MF = Marshy floating, MRB = Marshy river beds, MAG = Marshy grassy plains, MRC = Moist rock crevices; Flowering and fruiting: First three letters of the month, Mar = March, Apr = April, May = May, Jun = June, Jul = July, Aug = August, Sep = September, Oct = October; Collection details: DD = Dipti Dey, PB = Puja Bhojak, BSA = B.S. Aswal, SKS = S.K. Srivastava, NLB = N.L. Bor, UCB = U.C. Bhattacharyya, NCN = N.C. Nair, MAR = M.A. Rau; Herbarium: GBP = G.B. Pant National Institute of Himalayan Environment, Almora, BSD = Herbarium of Botanical Survey of India, Northern Regional Centre, Dehradun, DD = Forest Research Institute, Dehradun, CAL = Central National Herbarium, Botanical Survey of India, Kolkata, CDRI = Central Drug Research Institute, Lucknow.

Botanical Name	Chandra Tal	Suraj Tal	Habit	Habitat	Elevation (m)	Flowering & fruiting	Voucher details
Apiaceae							
<i>Bupleurum falcatum</i> L.** (Fig. 3D)	+		H	DR, SS	3600–4200	Jul–Sept	DD & PB 3208, 4104, 4165, 4637 (GBP)
<i>Hymenidium stellatum</i> (D.Don) Pimenov & Kljuykov (Fig. 5F)		+	H	DRS	4600–4800	Jul–Sept	DD & PB 4636, 4670 (GBP); BSA 10709 (CDRI)
<i>Pleurospermum candollei</i> (DC.) Benth. ex C.B.Clarke** (Fig. 5E)		+	H	DRS	4600–4800	Jul–Sept	DD & PB 3275, 4676, 4685 (GBP); BSA 10980 (CDRI)
<i>Vicatia coniiifolia</i> DC.	+		H	MGS	3600–3800	May–Sept	BSA 10499 (CDRI)
Asteraceae							
<i>Ajania tibetica</i> (Hook.f. & Thomson ex C.B.Clarke) Tzvelev		+	H	MGM	4600–4800	Jun–Aug	BSA 10736 (CDRI)
<i>Allardia glabra</i> Decne.** (Fig. 5I)		+	H	MS	4600–4800	Jul–Sept	DD & PB 4654 (GBP); BSA 10728 (CDRI)
<i>Allardia nivea</i> Hook.f. & Thomson ex C.B.Clarke		+	H	DRS	4600–4800	Aug–Sept	DD & PB 3282, 4641, 4658 (GBP)
<i>Allardia tomentosa</i> Decne. (Fig. 6A)	+	+	H	DSS	4200–4800	Jul–Sept	DD & PB 3277, 4132 (GBP); BSA 10722, 10731 (CDRI)
<i>Anaphalis contorta</i> (D.Don) Hook.f.		+	H	DRS	3200–4800	Jun–Aug	DD & PB 3298, 4659 (GBP)
<i>Anaphalis nepalensis</i> (Spreng.) Hand.-Mazz.	+		H	MS	3400–3600	Jun–Sept	BSA 6746 (CDRI); SKS 108312 (BSD)!
<i>Anaphalis triplinervis</i> (Sims) C.B.Clarke	+		H	DR, RB	3200–4200	Jul–Sept	DD & PB 3209 (GBP); SKS 103080, 107087 (BSD)!
<i>Aster asterodes</i> Kuntze		+	H	MR	4600–4800	Jun–Aug	DD & PB 3289, 4684 (GBP)
<i>Aster flaccidus</i> Bunge	+	+	H	MR	3600–4800	Jul–Sept	DD & PB 3270, 3280, 4126, 4663 (GBP); SKS 105615 (BSD); BSA 10724 (CDRI)
<i>Cremanthodium decaisnei</i> C.B.Clarke**		+	H	MGM	4400–4800	Jul–Sept	DD & PB 4668 (GBP); NLB 16359 (DD)!
<i>Crepis multicaulis</i> Ledeb.	+	+	H	MOR, SS	4200–4800	Jun–Jul	DD & PB 3259, 3260, 4631 (GBP); SKS 103091 (BSD)!
<i>Erigeron multiradiatus</i> (Lindl. ex DC.) Benth. & Hook.f.	+		H	MG, RB	3200–3600	Jun–Sept	DD & PB 4189 (GBP); SKS 100319 (BSD)!
<i>Inula royleana</i> DC.		+	H	MR	3200–4000	Jul–Sept	DD & PB 4192, 4606 (GBP)
<i>Jurinea ceratocarpa</i> var. <i>depressa</i> C.B.Clarke ex Hook.f.	+		H	MST	3600–4200	Jul–Aug	DD & PB 3267 (GBP)
<i>Lactuca macrorhiza</i> (Royle) Hook.f.	+		H	MR	4200–4300	Jul–Sept	DD & PB 4628 (GBP)
<i>Leontopodium brachyactis</i> Gand.	+	+	H	MST	3400–4600	Jul–Aug	DD & PB 4630, 4660 (GBP); UCB 49288 (BSD)!
<i>Leontopodium himalayanum</i> DC.	+		H	MR	4200–4300	Jul–Oct	DD & PB 4113, 4155, 4173 (GBP); SKS 103039 (BSD)!, BSA 6966 (CDRI)
<i>Leontopodium nanum</i> (Hook.f. & Thomson ex C.B.Clarke) Hand.-Mazz.	+	+	H	DGR	3600–4800	Jul–Oct	DD & PB 3297 (GBP); SKS 100368 (BSD)!, NCN 16763 (BSD)!
<i>Neobrachyactis roylei</i> (DC.) Brouillet	+		H	MR	4250–4300	Jul–Sept	DD & PB 3252 (GBP); SKS 98997 (BSD)!
<i>Psychogeton poncinsii</i> (Franch.) Y.Ling & Y.L.Chen (Fig. 5H)	+	+	H	MOR, RB	4200–4800	Jun–Sept	DD & PB 3243, 4139, 4172 (GBP); BSA 10974 (CDRI)
<i>Richteria pyrethroides</i> Kar. & Kir.(Fig. 4J)	+		H	DST	3300–4800	Jun–Aug	DD & PB 4133 (GBP)
<i>Saussurea glacialis</i> Herder (Fig. 5L)		+	H	MST	3800–4800	Jul–Aug	DD & PB 3281, 4632 (GBP)
<i>Saussurea gnaphalodes</i> (Royle ex DC.)		+	H	MGM	4600–4800	Jul–Aug	BSA 10707 (CDRI)
<i>Saussurea gossypiphora</i> D. Don.**		+	H	MST	4300–5000	Jul–Sept	DD & PB 4188, 4190 (GBP)
<i>Sericocarpus asteroides</i> (L.) Britton, Sterns & Poggenb.**	+		H	MSS	4250–4300	Jul–Sept	DD & PB 3210, 3251, 4115 (GBP), SKS 100840 (BSD)!
<i>Taraxacum eriopodum</i> DC.	+		H	MS	3200–3800	Jun–Sept	SKS 103053 (BSD)!
<i>Taraxacum leucanthum</i> (Ledeb.) Ledeb.	+		H	MR	4250–4300	Jul–Sept	SKS 103038 (BSD)!
<i>Taraxacum officinale</i> F.H.Wigg. (Fig. 4L)	+		H	MR	3200–3800	Jun–Sept	DD & PB 3230, 4140 (GBP); SKS 100381 (BSD)!, NCN 16767 (BSD)!
Boraginaceae							
<i>Arnebia euchroma</i> (Royle ex Benth.) I.M.Johnst.** (Fig. 3B)	+		H	DST	3500–4000	Jun–Jul	DD & PB 4136 (GBP)
<i>Eritrichium nanum</i> (L.) Gaudin	+		H	MS	3400–4000	Jun–Aug	BSA 10238 (CDRI); SKS 103037A (BSD)!
<i>Eritrichium spathulatum</i> (Benth.) C.B.Clarke		+	H	MGM	4600–4800	Jul–Aug	NLB 8671 (DD)!
<i>Eritrichium villosum</i> (Ledeb.) Bunge		+	H	DST	4000–4800	Jun–Aug	DD & PB 3295, 4673, 4683 (GBP); NLB 15448 (DD)!
<i>Myosotis sylvatica</i> Ehrh. ex Hoffm. (Fig. 3H)	+		H	DST	3200–4000	Jun–Aug	SKS 103037B (BSD)!

Botanical Name	Chandra Tal	Suraj Tal	Habit	Habitat	Elevation (m)	Flowering & fruiting	Voucher details
<i>Myosotis verna</i> Nutt.	+		H	MRC	3200–3600	May–Jun	DD & PB 4175, 4176 (GBP)
Brassicaceae							
<i>Aphragmus oxycarpus</i> (Hook.f. & Thomson) Jafri (Fig. 4A)		+	H	DRC	3600–4800	Jun–Jul	NLB 15221 (DD)!
<i>Arabis amplexicaulis</i> Edgew.	+		H	MS	3200–4000	Jun–Sept	SKS 103071 (BSD)!
<i>Arabis recta</i> Vill.	+		H	MM	3600–4000	Jun–Sept	DD & PB 3255, 4108 (GBP); SKS 103049 (BSD)!
<i>Braya rosea</i> Bunge		+	H	DGM	4600–4800	Jun–Aug	NLB 213 (DD)!
<i>Chorispورا sabulosa</i> Cambess. (Fig. 4B)		+	H	MGM	3800–4800	Jun–Aug	DD & PB 3291, 4646 (GBP)
<i>Crucihimalaya tibetica</i> (Hook.f. & Thomson) Al-Shehbaz, D.A.German & M.Koch	+		H	MS	3200–4000	Jun–Sept	SKS 103069 (BSD)!
<i>Crucihimalaya wallichii</i> (Hook.f. & Thomson) Al-Shehbaz, O’Kane & R.A.Price	+		H	MGR	4200–4300	Apr–Aug	DD & PB 4129 (GBP)
<i>Dilophia salsa</i> Thomson		+	H	MGM	4600–4800	Jun–Jul	BSA 11005 (CDRI)
<i>Draba altaica</i> (C.A. Mey.) Bunge		+	H	DST	4600–4800	Jun–Aug	BSA 10723 (CDRI); SKS 103103 (BSD)!
<i>Draba glomerata</i> Royle	+	+	H	MST	3800–4800	Jun–Aug	DD & PB 2557 (GBP); SKS 103029 (BSD)!, UCB 40839 (BSD)!
<i>Draba lanceolata</i> Royle	+		H	MST	3200–3800	Jun–Aug	SKS 100380 (BSD)!
<i>Draba oreades</i> Schrenk (Fig. 5C)		+	H	MST	4600–4800	Jun–Aug	DD & PB 4639 (GBP)
<i>Draba setosa</i> Royle		+	H	DST, GM	4600–4800	May–Aug	DD & PB 4661, 4680 (GBP); BSA 10720 (CDRI)
<i>Sisymbrium orientale</i> L.		+	H	MOR	4000–4600	Apr–Aug	DD & PB 4682 (GBP)
Campanulaceae							
<i>Cyananthus lobatus</i> Wall. ex Benth.	+		H	MS	3300–4500	Jul–Sept	DD & PB 4629 (GBP)
Caprifoliaceae							
<i>Lonicera spinosa</i> (Decne.) Jacq. ex Walp. (Fig. 6H)	+	+	Sh	DST	3600–4600	Jun–Jul	DD & PB 4153 (GBP); NLB 8698 (DD)!
Caryophyllaceae							
<i>Cerastium glomeratum</i> Thuill.		+	H	MS	3800–4200	Jun–Sept	DD & PB 2559 (GBP)
<i>Cherleria biflora</i> (L.) A.J.Moore & Dillenb.		+	H	MST	4600–4800	Jul–Sept	BSA 10297 (CDRI)
<i>Dichodon cerastoides</i> (L.) Rchb.(Fig. 5A)	+	+	H	MR	4200–4800	May–Aug	DD & PB 4645 (GBP); UCB 40826 (BSD)!
<i>Eremogone kansuensis</i> (Maxim.) Dillenb. & Kadereit	+		H	MR	3600–4000	Jun–Jul	DD & PB 4122 (GBP)
<i>Silene gonosperma</i> (Rupr.) Bocquet	+	+	H	MSS	3200–4400	Jun–Jul	DD & PB 4687 (GBP); SKS 100397 (BSD)!
<i>Silene graminifolia</i> Otth	+		H	DST	4250–4300	Jun–Jul	DD & PB 3244, 4603 (GBP)
<i>Silene nepalensis</i> Majumdar		+	H	MSH	3400–4200	Jul–Oct	DD & PB 4652 (GBP)
<i>Silene songarica</i> (Fisch., C.A. Mey. & Avé-Lall.) Bocquet		+	H	DBS	3200–4600	Jun–Sept	DD & PB 3287 (GBP)
<i>Silene uralensis</i> (Rupr.) Bocquet	+		H	MS	3800–4200	Jun–Jul	UCB 49453 (BSD)!
<i>Stellaria decumbens</i> Edgew.	+	+	H	MSS	3400–4200	Jun–Sept	DD & PB 3274, 4120, 4124, 4657 (GBP); SKS 107131 (BSD)!
<i>Stellaria longifolia</i> Muhl. ex Willd.	+		H	MSS	3200–3400	May–Jul	DD & PB 3237 GBP
<i>Stellaria williamsiana</i> Kozhevnikov.	+		H	MSS	3200–3800	Jul–Aug	DD & PB 3224, 4107, 4128 (GBP)
<i>Thylacospermum caespitosum</i> (Cambess.) Schischk.		+	H	DBS	4400–4800	Jun–Sept	DD & PB 4626 (GBP); BSA 10706 (CDRI)
Crassulaceae							
<i>Hylotelephium ewersii</i> (Ledeb.) H.Ohba**		+	H	MBS	3600–4500	Jul–Sept	DD & PB 4649, 4679, 4681 (GBP)
<i>Rhodiola crenulata</i> (Hook. f. & Thomson) H. Ohba	+	+	H	MS, MRC	3600–4800	Jun–Sept	DD & PB 3245, 4166, 4199, 4643, 4672, 4888 (GBP); BSA 10717 (CDRI)
<i>Rhodiola heterodonta</i> (Hook. f. & Thomson) Boriss.		+	H	DRS	3300–5000	Jun–Aug	DD & PB 4620 (GBP)
<i>Rhodiola himalensis</i> (D. Don) S.H. Fu (Fig. 5J)	+		H	MR	4250–4300	Jun–Aug	DD & PB 4121, 4198 (GBP)
<i>Rhodiola imbricata</i> Edgew. (Fig. 5K)		+	H	DST	4200–4800	Jun–Aug	DD & PB 3276, 4651 (GBP)
<i>Rosularia alpestris</i> (Kar. & Kir.) Boriss. (Fig. 6M)	+		H	MST	3200–3800	Jun–Jul	DD & PB 3217, 4168 (GBP)
Cyperaceae							
<i>Carex borii</i> Nelmès		+	Se	DGS	3800–4900	Jun–Aug	BSA 11001 (CDRI)
<i>Carex infuscata</i> Nees		+	Se	MR	4600–4800	Jul–Sept	BSA 10292 (CDRI)
<i>Carex maritima</i> Gunnerus (Fig. 6C)		+	Se	MR	4600–4800	Jun–Jul	DD & PB 2558B (GBP)
<i>Carex melanantha</i> C.A. Mey.	+		Se	MSS	4200–4400	Jul–Aug	DD & PB 3266, 4184 (GBP), SKS 107111 (BSD)!
<i>Carex micropoda</i> C.A.Mey. (Fig. 6D)	+	+	Se	MSS	4200–4800	Jul–Aug	DD & PB 3288, 4623 (GBP), BSA 10973 (CDRI)
<i>Carex nudicarpa</i> (Y.C.Yang) S.R.Zhang		+	Se	MSS	4600–4800	Jul–Aug	UCB 40828 (BSD)!
<i>Carex ovoidispica</i> O.Yano		+	Se	MSS	4600–4800	Jul–Aug	NLB 171 (DD)!
<i>Carex parvula</i> O.Yano		+	Se	MSS	4600–4800	Jul–Aug	BSA 10998 (CDRI)
<i>Carex pamirensis</i> C.B. Clarke	+		Se	MSH	4200–4400	Jul–Sept	DD & PB 4697 (GBP)
<i>Eleocharis palustris</i> (L.) Roem. & Schult.	+	+	Se	MRB	4200–4800	May–Sept	DD & PB 3211 (GBP)
Ephedraceae							
<i>Ephedra intermedia</i> Schrenk & C.A.Mey. (Fig. 4E)	+	+	Sh	DRC	3600–4800	Jul–Oct	DD & PB 3242, 4148, 4194, 4648, 4692 (GBP)

Botanical Name	Chandra Tal	Suraj Tal	Habit	Habitat	Elevation (m)	Flowering & fruiting	Voucher details
Fabaceae							
<i>Astragalus cariensis</i> Boiss. (Fig. 6B)	+		H	DS, RB	3600–4200	Jun–Aug	DD & PB 3265, 4111 (GBP); SKS 103092, 103093 (BSD)!
<i>Astragalus himalayanus</i> Klotzsch	+		H	MR	3200–3800	Jun–Sept	DD & PB 3263B (GBP)
<i>Astragalus strictus</i> Benth.	+		H	MSH, MST	3200–3600	Jul–Sept	DD & PB 3221, 4112 (GBP); NCN 21073 (BSD)!
<i>Cicer microphyllum</i> Royle ex Benth.	+		H	DSS	3200–4000	Jun–Aug	DD& PB 3253, 4131 (GBP); SKS 107096 (BSD)!
<i>Oxytropis humifusa</i> Kar. & Kir.	+		H	MS	3200–4000	Jul–Sept	SKS 103034 (BSD)!
<i>Oxytropis lapponica</i> (Wahlenb.) J.Gay	+	+	H	MS, RB, DR	3200–4800	Jun–Aug	DD & PB 3214, 4106, 4149, 4178, 4696 (GBP); SKS 100391 (BSD)!
<i>Oxytropis microphylla</i> (Pall.) DC.		+	H	MGM	4600–4800	Jun–Aug	NLB 8659 (DD)!
<i>Oxytropis mollis</i> Royle ex Benth.	+	+	H	MSS	4200–4800	May–Sept	DD & PB 3263A, 3296 (GBP); SKS 103031, 103075 (BSD)!
<i>Trigonella emodi</i> Benth.	+		H	MS	3200–3600	Jun–Sept	DD & PB 3233 (GBP)
Gentianaceae							
<i>Comastoma tenellum</i> (Rottb.) Toyok.	+		H	MRB	3600–4000	Jul–Aug	DD & PB 3257A (GBP)
<i>Gentiana argentea</i> (Royle ex D.Don) Royle ex D.Don	+		H	MME	3600–4400	Apr–Jul	SKS 103046, 107114 (BSD)!
<i>Gentiana coronata</i> Royle	+		H	MR	4250–4300	Jun–Aug	DD & PB 3247 (GBP)
<i>Gentiana leucomelaena</i> Maxim.	+	+	H	MS	3400–4800	May–Aug	DD & PB 3220A (GBP); BSA 10291 (CDRI)
<i>Gentiana nivalis</i> L. (Fig. 6E)	+		H	MAG	3200–3800	Aug–Oct	DD & PB 3220B, 4174 (GBP)
<i>Gentiana nubigena</i> Edgew.		+	H	MME	4600–4800	Jul–Aug	UCB 52337 (BSD)!
<i>Gentiana phyllocalyx</i> C.B. Clarke	+		H	MR	4200–4300	Jun–Oct	DD & PB 4193 (GBP)
<i>Gentianella aurea</i> (L.) Harry Sm.	+		H	MG	4200–4600	Jun–Aug	BSA 6671 (CDRI)
<i>Gentiana membranulifera</i> T.N.Ho	+		H	MR	4200–4300	May–Aug	DD & PB 3234, 4144 (GBP)
<i>Gentianella moorcroftiana</i> (Wall. ex Griseb.) Airy Shaw	+		H	MME	3200–4200	Jul–Aug	UCB 49447 (BSD)!
<i>Gentianopsis detonsa</i> (Rottb.) Ma**	+		H	MR	4200–4300	Jul–Oct	DD & PB 3226, 4118 (GBP)
<i>Gentianopsis paludosa</i> (Hook.f.) Ma	+		H	MR	3800–4400	Jul–Aug	UCB 52210 (BSD)!
<i>Lomatogonium carinthiacum</i> (Wulfen) A.Braun	+		H	MR	4200–4300	Jul–Oct	DD & PB 4186 (GBP); SKS 100388 (BSD)!
Geraniaceae							
<i>Geranium pratense</i> L.	+		H	DS	3200–3800	Jul–Aug	DD & PB 3249 (GBP)
<i>Geranium wallichianum</i> D. Don ex Sweet** (Fig. 3E)	+		H	MST	3200–3800	Jun–Sept	SKS 100309 (BSD)!
Juncaceae							
<i>Juncus allioides</i> Franch. (Fig. 6F)	+		Ru	MR	4250–4300	Jul–Aug	DD & PB 3246 (GBP)
<i>Juncus himalensis</i> Klotzsch (Fig. 6G)	+		Ru	MR	4200–4300	Jun–Aug	DD & PB 4611 (GBP)
<i>Juncus leucomelas</i> Royle ex D. Don	+		Ru	MR	4200–4300	Jul–Aug	DD & PB 3240 (GBP)
Juncaginaceae							
<i>Triglochin maritima</i> L.	+		H	MAS	3200–4600	May–Oct	DD & PB 3213, 4102, 4146, 4147 (GBP), SKS 108319 (BSD)!
Lamiaceae							
<i>Elsholtzia eriostachya</i> (Benth.) Benth. (Fig. 4D)	+		H	MS	3200–4600	Jul–Sept	DD & PB 3225, 4125, 4152, 4617 (GBP)
<i>Nepeta eriostachya</i> Benth.**	+	+	H	MS	3200–4800	Jul–Sept	DD & PB 3223, 4162, 4635 (GBP); SKS 108307 (BSD)!
<i>Nepeta longibracteata</i> Benth. (Fig. 5D)		+	H	DGS	4400–4800	Jul–Aug	DD & PB 3284, 4642, 4694 (GBP); BSA 10725 (CDRI)
<i>Thymus linearis</i> Benth. (Fig. 4K)	+		H	MSS	3200–4000	Jul–Sept	DD & PB 3241, 4156, 4160, 4177 (GBP); SKS 103079 (BSD)!; BSA 8821 (CDRI)
Liliaceae							
<i>Gagea gageoides</i> (Zucc.) Vved.		+	H	DBS	4600–4800	Jul–Aug	BSA 10327 (CDRI)
<i>Gagea serotina</i> (L.) Ker Gawl. (Fig. 4G)		+	H	MST	4600–4800	Jun–Aug	DD & PB 4677, 4689 (GBP)
Onagraceae							
<i>Epilobium latifolium</i> L.		+	H	DST	4000–4800	Jul–Sept	DD & PB 3290 (GBP)
<i>Epilobium laxum</i> Royle	+		H	MR	3200–4200	Jul–Sept	DD & PB 3231 (GBP)
<i>Epilobium leiophyllum</i> Hausskn.		+	H	MGM	4600–4800	Jul–Aug	BSA 10733 (CDRI)
<i>Epilobium palustre</i> L.	+		H	MS, RB	3200–3800	Jun–Sept	DD & PB 4110 (GBP)
<i>Epilobium royleanum</i> Hausskn. (Fig. 4F)	+		H	MGM	4200–4600	Jun–Aug	SKS 100386 (BSD)!
Orobanchaceae							
<i>Euphrasia himalayica</i> Wettst.	+		H	MS	3600–4200	May–Jul	DD & PB 3261 (GBP)
<i>Pedicularis hoffmeisteri</i> Klotzsch	+		H	MS	4200–4300	Jun–Aug	DD & PB 4130, 4195 (GBP)
<i>Pedicularis longiflora</i> Rudolph (Fig. 6J)	+		H	MR	3200–4200	Jun–Aug	DD & PB 4616 (GBP)
<i>Pedicularis pectinata</i> Wall. ex Benn.	+		H	MR	3200–3600	Jun–Aug	DD & PB 4145, 4163 (GBP); SKS 108309 (BSD)
<i>Pedicularis rhinanthoides</i> Schrenk (Fig. 6K)	+		H	MR	3200–4200	Jul–Sept	DD & PB 3238, 3248 (GBP)
<i>Pedicularis roylei</i> Maxim.		+	H	MGM	4200–4850	Jul–Aug	DD & PB 4669, 4693 (GBP), UCB 52339 (BSD)!; BSA 10982 (CDRI)
Papaveraceae							
<i>Corydalis crassifolia</i> Royle		+	H	MGM	4600–4800	Jul–Aug	NLB 13983 (DD)!
<i>Corydalis govaniana</i> Wall.** (Fig. 5B)		+	H	DST	3400–4800	May–Aug	DD & PB 3283 (GBP)
<i>Corydalis meifolia</i> Wall.**	+	+	H	MST	3600–4800	Jun–Aug	DD & PB 3257B, 3286, 4665 (GBP); BSA 10995 (CDRI)
<i>Corydalis moorcroftiana</i> Wall. ex Hook. f. & Thomson		+	H	MST	4000–4800	Jul–Aug	DD & PB 4678, 4686 (GBP)

Botanical Name	Chandra Tal	Suraj Tal	Habit	Habitat	Elevation (m)	Flowering & fruiting	Voucher details
<i>Papaver guilelmi-waldemarii</i> (Klotzsch) Christenh. & Byng (Fig. 3G)		+	H	DRC	3400–4800	Jul–Oct	MAR 5913 (BSD)!
Plantaginaceae							
<i>Hippuris vulgaris</i> L. (Fig. 3F)	+		H	MAS	3200–3800	Jun–Jul	DD & PB 4151 (GBP)
<i>Veronica beccabunga</i> L. (Fig. 3L)	+		H	MR	3200–3600	Jun–Sept	DD & PB 3227,4119, 4157 (GBP); SKS 103113 (BSD)!
<i>Veronica biloba</i> Schreb. ex L.	+		H	MR	3200–3600	Jul–Sept	DD & PB 4103, 4164 (GBP)
Poaceae							
<i>Agrostis castellana</i> Boiss. & Reut.	+		Gr	MS	3800–4400	Jul–Sept	DD & PB 4159, 4610 (GBP)
<i>Elymus dahuricus</i> Turcz. ex Griseb.		+	Gr	MS	4600–4800	Jul–Aug	NLB 326 (DD)!
<i>Festuca valesiaca</i> Schleich. ex Gaudin		+	Gr	MS	4600–4800	Jun–Aug	NLB 15070 (DD)!
<i>Melica persica</i> Kunth	+	+	Gr	DS	4200–4800	May–Aug	DD & PB 4601, 4602 (GBP)
<i>Phleum alpinum</i> L.	+		Gr	MS	3200–4000	Jul–Sept	SKS 100333 (BSD)!
<i>Poa annua</i> L.		+	Gr	MRC	4600–4800	Jun–Jul	NCN 16496 (BSD)!
<i>Poa alpina</i> L.	+		Gr	GM	4200–4300	Jul–Aug	SKS 103104, 103114 (BSD)!
<i>Poa glauca</i> Vahl		+	Gr	MAP	4600–4800	Jun–Jul	NLB 13972 (DD)
<i>Poa persica</i> Trin.		+	Gr	MRC	4600–4800	Jun–Jul	NLB 12122 (DD)!
<i>Poa supina</i> Schrad.	+		Gr	GM	4200–4300	Jun–Jul	UCB 48763 (BSD)!, NCN 17065 (BSD)!
<i>Puccinellia kashmiriana</i> Bor		+	Gr	MAP	4600–4800	Jul–Aug	NLB 16360 (DD)
<i>Trisetum spicatum</i> (L.) K.Richt.	+		Gr	GM	4200–4300	Jul–Aug	UCB 45071(BSD)!
Polygonaceae							
<i>Bistorta affinis</i> (D.Don) Greene	+	+	H	MG	4200–4800	Jun–Sept	DD & PB 3207, 4197, 4619 (GBP); SKS 100369, 103056, (BSD)!
<i>Bistorta vivipara</i> (L.) Delarbre	+		H	MG	3200–4800	Jun–Aug	DD & PB 3215, 4621 (GBP); SKS 100376 (BSD)!
<i>Oxyria digyna</i> (L.) Hill (Fig. 6I)	+	+	H	DR	3200–4800	Jun–Sept	DD & PB 3258 (GBP); SKS 103078, 103109 (BSD)!
<i>Polygonum aviculare</i> L.	+		H	MG	3200–3800	Jul–Sept	DD & PB 4171 (GBP)
<i>Polygonum cognatum</i> Meisn. (Fig. 5G)	+	+	H	MG	3200–3800	Jul–Sept	DD & PB 3228, 4117, 4634, 4664 (GBP); SKS 103085, 106265, 107148 (BSD)!
<i>Polygonum paronychioides</i> C.A. Mey.	+	+	H	DR	3200–3800	Jun–Sept	DD & PB 3273, 4154, 4653 (GBP)
<i>Polygonum recumbens</i> Royle ex Bab.	+		H	MS	3200–3800	Jun–Aug	SKS 108321 (BSD)!
<i>Polygonum rottboellioides</i> Jaub. & Spach	+		H	MS	3200–3800	Jun–Sept	SKS 107149 (BSD)!
<i>Rheum spiciforme</i> Royle** (Fig. 3J)	+	+	H	MSS	3200–4800	Jun–Aug	DD & PB 3735, 4622 (GBP); BSA 10967 (CDRI)
Potamogetonaceae							
<i>Potamogeton crispus</i> L.	+	+	H	MF	3200–4200	May–Aug	SKS 100398 (BSD)!
<i>Potamogeton natans</i> L.	+		H	MF	3200–4200	May–Aug	DD & PB 4116 (GBP)
<i>Potamogeton nodosus</i> Poir. (Fig. 6L)	+		H	MSW	3200–4200	May–Aug	DD & PB 4150 (GBP)
<i>Stuckenia pectinata</i> (L.) Börner (Fig. 3K)	+		H	MSW	4200–4400	May–Oct	DD & PB 3254, 4123, 4618 (GBP)
Primulaceae							
<i>Androsace sempervivoides</i> Jacquem. ex Duby	+		H	MS	3600–4800	Jun–Aug	DD & PB 4141 (GBP)
<i>Primula minutissima</i> Jacquem. ex Duby (Fig. 4I)	+	+	H	MS	3400–4600	Jun–Jul	DD & PB 4655 (GBP)
Ranunculaceae							
<i>Aconitum rotundifolium</i> Kar. & Kir.		+	H	MST	4600–4800	Jul–Sept	NLB 224 (DD)!
<i>Aconitum violaceum</i> Jacquem. ex Stapf** (Fig. 3A)	+		H	MS	3400–4800	Jul–Sept	NCN 16764 (BSD)!
<i>Delphinium brunonianum</i> Royle** (Fig. 4C)		+	H	DST	4200–4800	Jul–Sept	DD & PB 3285, 4612 (GBP); BSA 10721 (CDRI)
<i>Eriocapitella rupicola</i> (Cambess.) Christenh. & Byng		+	H	MGM	4600–4800	Jul–Sept	BSA 10296 (CDRI)
<i>Halerpestes tricuspis</i> (Maxim.) Hand.-Mazz.	+	+	H	MAS	3200–4800	Jun–Jul	DD & PB 3216, 3229, 4109, 4143, 4691 (GBP); SKS 103059, 103102 (BSD)!
<i>Oxygraphis endlicheri</i> (Walp.) Bennet & Sum. Chandra		+	H	MS	3200–4900	Jun–Aug	BSA 10189 (CDRI)
<i>Ranunculus adoxifolius</i> Hand.-Mazz.		+	H	MGM	4600–4800	Jul–Aug	BSA 11002 (CDRI)
<i>Ranunculus bulbosus</i> L.		+	H	MS	3200–3800	Apr–Jun	DD & PB 4674 (GBP)
<i>Ranunculus hirtellus</i> Royle**		+	H	MS	4200–4900	May–Jul	DD & PB 3300, 4671 (GBP); UCB 71239 (BSD)!
<i>Ranunculus pulchellus</i> C.A. Mey.	+		H	MG, RB	3200–3800	Jun–Oct	SKS 103048, 103062 (BSD)!
<i>Ranunculus trichophyllus</i> Chaix. (Fig. 3I)	+		H	MSW	3200–4200	May–Aug	SKS 100395 (BSD)!
<i>Ranunculus trivedii</i> Aswal & Mehrotra	+	+	H	MAS	3200–4800	Jun–Aug	DD & PB 3250, 4169, 4647 (GBP); NLB 15136 (DD)!
Rosaceae							
<i>Potentilla argrophylla</i> Wall. ex Lehm. (Fig. 4H)	+	+	H	DS, RB	4200–4800	Jun–Aug	DD & PB 4633, 4656, 4667 (GBP); SKS 103022 (BSD)!
<i>Potentilla crantzii</i> (Crantz) Beck ex Fritsch	+		H	DS	3200–4200	Jun–Aug	DD & PB 3264 (GBP); SKS 107029 (BSD)!
<i>Potentilla multifida</i> L.	+		H	MS, RB	3200–4200	Jun–Aug	DD & PB 3222, 3272, 4161, 4605 (GBP); SKS 103067 (BSD)!
<i>Potentilla nivea</i> L.		+	H	DST	3200–4800	Jul–Aug	DD & PB 4644, 4662, 4666 (GBP); BSA 10295 (CDRI)
<i>Potentilla tetrandra</i> (Bunge) Hook.f.		+	H	DST	4200–4800	May–Aug	DD & PB 3292, 4690 (GBP)
<i>Sibbaldia parviflora</i> Willd.	+		H	DST	3200–4200	Jun–Aug	DD & PB 3262 (GBP)
Rubiaceae							
<i>Galium acutum</i> Edgew.	+		H	MS	3600–4200	Jun–Aug	DD & PB 4187 (GBP)

Botanical Name	Chandra Tal	Suraj Tal	Habit	Habitat	Elevation (m)	Flowering & fruiting	Voucher details
<i>Galium aparine</i> L.	+		H	MS	3200–3800	Jun–Aug	DD & PB 3256 (GBP); SKS 107022 (BSD)!
Saxifragaceae							
<i>Bergenia ciliata</i> (Haw.) Sternb. (Fig. 3C)	+		H	MOR	3800–4200	Mar–Jul	DD & PB 4135 (GBP)
<i>Saxifraga flagellaris</i> Willd. (Fig. 6N)	+	+	H	MST	3600–4890	Jul–Aug	DD & PB 3218, 3299, 4182, 4183 (GBP)
<i>Saxifraga hirculus</i> L.	+	+	H	MST	3800–4800	Jun–Sept	DD & PB 3268, 3293, 3294 (GBP); SKS 107162 (BSD)!
<i>Saxifraga sibirica</i> L.	+	+	H	MST	3800–4200	Jun–Sept	SKS 103055 (BSD)!
<i>Saxifraga Jacquemontiana</i> Decne. (Fig. 6O)	+	+	H	MS	3800–4900	Jul–Sept	DD & PB 4158, 4640 (GBP); BSA 10986 (CDRI)

cylindrical. Involucral bracts linear-oblong. Corolla purple. Pappus hairs few or many, scabrid, light brown or blackish.

Threat status. Critically Endangered.

Boraginaceae

Arnebia euchroma (Royle ex Benth.) I.M. Johnst.

Pink Arnebia

Material examined. INDIA – **Himachal Pradesh** • Rare species occurring on dry and stony slopes, Lahaul-Spiti district, Chandra Tal; 32°28.589’N, 077°36.951’E; alt. 3920 m; 13.07.2017; DD & PB 4136 (GBP).

Identification. Perennial herbs with thick purple root. Stems covered with white trichomes. Basal leaves with petiole; middle and upper cauline leaves sessile, lanceolate. Inflorescence cymes, many flowered. Corolla funnel shaped, pink or pink white. Nuts irregularly and coarsely tuberculate, greyish.

Threat status. Critically Endangered.

Crassulaceae

Rhodiola heterodonta (Hook. f. & Thomson) Boriss.

Toothed Rhodiola

Material examined. INDIA – **Himachal Pradesh** • Rare species occurring on rocky slopes, Lahaul-Spiti district, Suraj Tal; 32°45.714’N, 077°23.885’E; alt. 4782 m; 19.06.2016; DD & PB 4620 (GBP).

Identification. Perennial herbs. Rhizomes thick. Stems erect. Leaves remotely arranged, alternate, sessile, triangular-ovate. Sepals glabrous, greenish. Petals rhombic-elliptic to oblong. Follicles brown. Seeds ellipsoid, brown.

Threat status. Vulnerable.

Papaveraceae

Papaver guilelmi-waldemarii (Klotzsch) Christenh. & Byng

Blue Poppy

Material examined. INDIA – **Himachal Pradesh** • Rare species occurring on rock crevices among boulders, Lahaul-Spiti district, Suraj Tal; 32°45.780’N, 077°23.952’E; alt. 4780 m; 27.06.1958; MAR 5913 (BSD).

Identification. Perennial, prickly, erect herb, Stem densely bristly. Radical leaves pinnately lobed, long petioled; cauline leaves sessile. Flowers blue to purplish

blue; pedicel spiny. Capsule dehiscent by 4–6 valves, 1–1.5 cm long. Seeds subreniform, brown.

Threat status. Endangered.

Polygonaceae

Rheum spiciforme Royle

Spiked Rhubarb

Material examined. INDIA – **Himachal Pradesh** • Scarcely occurring on moist sandy slopes, Lahaul-Spiti district, Chandra Tal; 32°29.121’N, 077°36.668’E; alt. 4257 m; 21.07.2016; DD & PB 3735; • Lahaul-Spiti district, Suraj Tal; 32°45.780’N, 077°23.952’E; alt. 4783 m; 11.07.2017; DD & PB 4622 (GBP).

Identification. Perennial, short, stout herb. Leaves ovate or ovate-elliptic. Petioles of basal leaf purplish red. Panicles spiciforme. Tepals light green, elliptic or oblong-elliptic. Fruits oblong-ellipsoid. Seeds round, brown.

Threat status. Vulnerable.

Ranunculaceae

Aconitum violaceum Jacquem. ex Stapf

Violet Monkshood, Mitha Telia

Material examined. INDIA – **Himachal Pradesh** • Occurring in moist meadows in scattered manner, Lahaul-Spiti district, Chandra Tal; 32°28.534’N, 077°36.990’E; alt. 4300 m; 08.08.1961; NCN 16764 (BSD).

Identification. Biennial herb. Roots paired, tuberculous. Stem 10–35 cm tall, erect. Leaves orbicular, lower leaves with long petiole, upper leaves sessile, lamina deeply 5-partite. Inflorescence dense raceme or corymbs. Flowers blue or violet, head ‘T’ shaped. Carpels 5. Follicles densely hairy. Seeds obpyramidal, brown.

Threat status. Vulnerable.

Discussion

In our study of Chandra Tal and Suraj Tal of Lahaul-Spiti, we found these two major high-altitude wetlands to harbor various vascular plant species valuable medicinal use or of conservation value due to their threatened, endemic, or native status. For the latter species, these two wetlands play an important role in their conservation. Due its high plant diversity, the Chandra Tal area has been considered one among the core areas of Cold Desert Biosphere Reserve. Among the 188 angiosperms recorded from these wetlands, dicots and monocots were



Figure 3. Vascular plants recorded in and around Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti. **A.** *Aconitum violaceum*. **B.** *Arnebia euchroma*. **C.** *Bergenia ciliata*. **D.** *Bupleurum falcatum*. **E.** *Geranium wallichianum*. **F.** *Hippuris vulgaris*. **G.** *Papaver guilelmi-waldemarii*. **H.** *Myosotis sylvatica*. **I.** *Ranunculus trichophyllus*. **J.** *Rheum spiciforme*. **K.** *Stuckenia pectinata*. **L.** *Veronica beccabunga*.



Figure 4. Vascular plants recorded in and around Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti. **A.** *Aphragmus oxycarpus*. **B.** *Chorisporea sabulosa*. **C.** *Delphinium brunonianum*. **D.** *Elsholtzia eriostachya*. **E.** *Ephedra intermedia*. **F.** *Epilobium royleanum*. **G.** *Gagea serotina*. **H.** *Potentilla argrophylla*. **I.** *Primula minutissima*. **J.** *Richteria pyrethroides*. **K.** *Thymus linearis*. **L.** *Taraxacum officinale*.

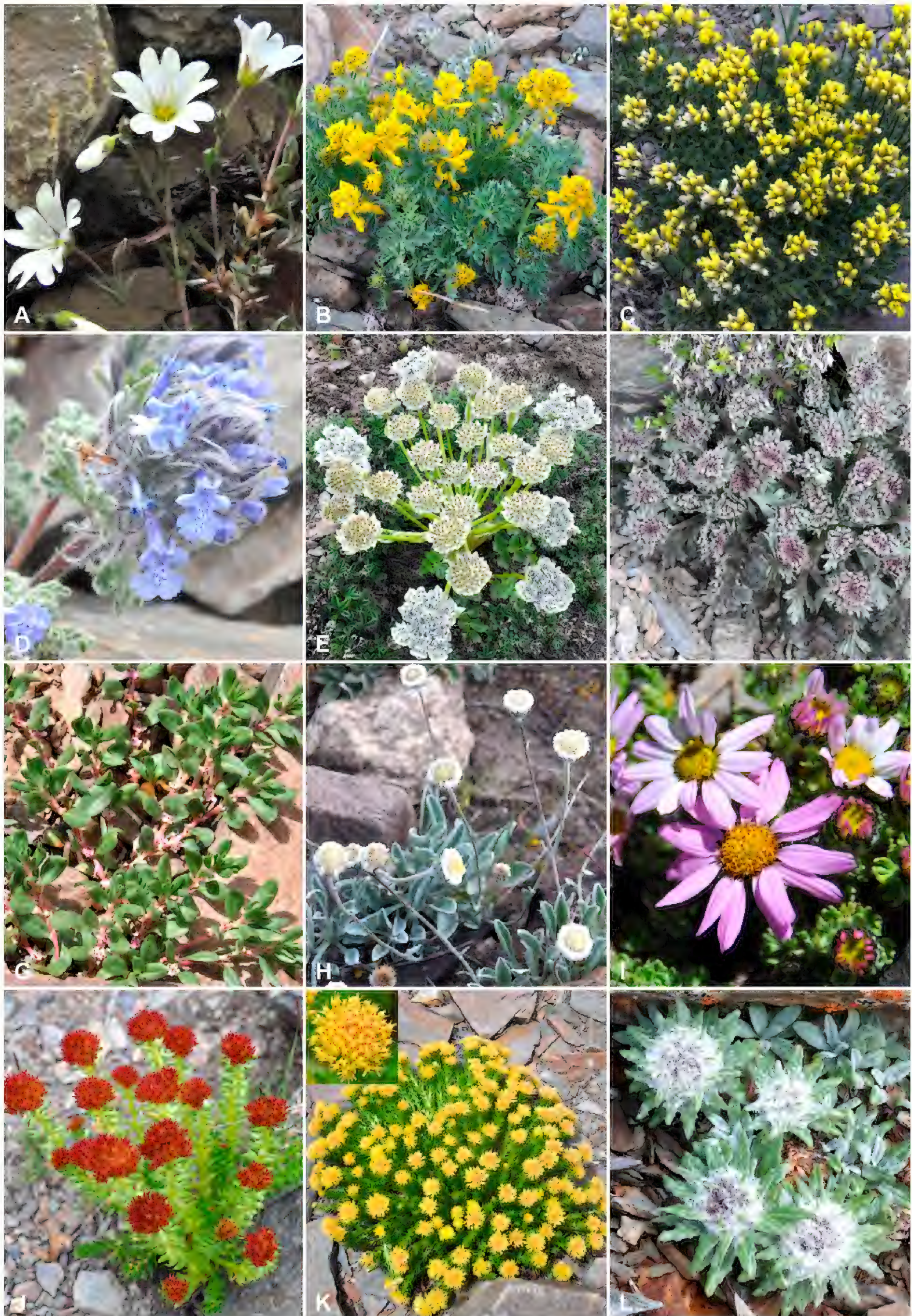


Figure 5. Vascular plants recorded in and around Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti. **A.** *Dichodon cerastoides*. **B.** *Corydalis govaniana*. **C.** *Draba oreades*. **D.** *Nepeta longibracteata*. **E.** *Pleurospermum candollei*. **F.** *Hymenidium stellatum*. **G.** *Polygonum cognatum*. **H.** *Psychrogeton poncinsii*. **I.** *Allardia glabra*. **J.** *Rhodiola himalensis*. **K.** *Rhodiola imbricata*. **L.** *Saussurea glacialis*.

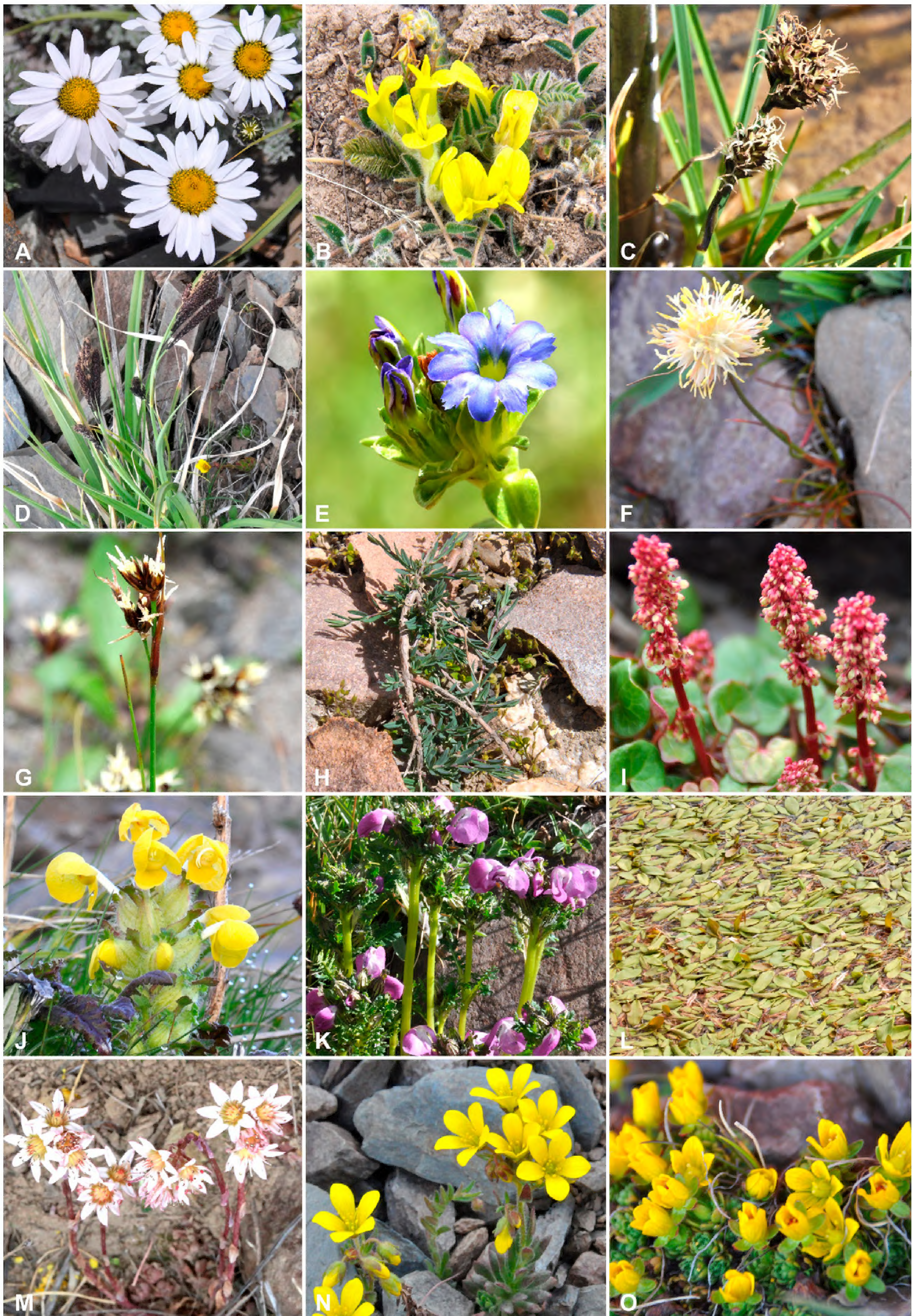


Figure 6. Vascular plants recorded in and around Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti. **A.** *Allardia tomentosa*. **B.** *Astragalus cariensis*. **C.** *Carex maritima*. **D.** *Carex micropoda*. **E.** *Gentiana nivalis*. **F.** *Juncus allioides*. **G.** *Juncus himalensis*. **H.** *Lonicera spinosa*. **I.** *Oxyria digyna*. **J.** *Pedicularis longiflora*. **K.** *Pedicularis rhinanthoides*. **L.** *Potamogeton nodosus*. **M.** *Rosularia alpestris*. **N.** *Saxifraga flagellaris*. **O.** *Saxifraga jacquemontiana*.

represented by 156 and 32 species, respectively. Floristic diversity was greater in Chandra Tal, with 125 species and one variety in 74 genera and 28 families, than in Suraj Tal with 98 species (in 59 genera and 23 families). Of all species recorded, 133 species (97 in Chandra Tal and 67 in Suraj Tal) were collected by us and 56 were compiled from the literature and herbaria. The two wetlands have 33 species in common. On the other hand, 93 and 65 species were exclusive in Chandra Tal and Suraj Tal, respectively. Among the 29 families recorded, over 81% of the total flora were represented by 16 dominant families. Asteraceae was the most dominant family (27 species and one variety), followed by Brassicaceae (14 species), Caryophyllaceae (13 species), Gentianaceae (13 species), Poaceae (12 species), Ranunculaceae (12 species), Cyperaceae (10 species), Fabaceae (nine species), Polygonaceae (nine species), Boraginaceae (six species), Crassulaceae (six species), Orobanchaceae (six species), Rosaceae (six species), Onagraceae, Papaveraceae, and Saxifragaceae (five species each) (Fig. 7). Campanulaceae, Caprifoliaceae, Ephedraceae, and Juncaginaceae were represented by a single species each. We found that

herbs (160 species and one variety, 85.2%) were dominant followed by grasses, rushes, and sedges (26 species, 13.8%), and shrubs (two species, 1.1%). We recorded the most species, 133 on moist slopes, followed by 43 species on rocky slopes, and 13 species on marshy slopes (Fig. 8). Chandra Tal had the greatest number of herbs (109 species and one variety) and grasses, rushes, and sedges (14 species) in comparison to Suraj Tal, which had 81 herb species and 15 grass, rush, and sedge species. Both wetlands had two shrubs each. Of the 188 species, six are threatened, 17 are native, and two (*Eritrichium nanum* and *Ranunculus trivedii*) are endemic to the Himalayan region.

During our field surveys, we observed high grazing pressure, heavy tourism, construction works and other anthropogenic activities, as well as harsh climatic conditions in both wetlands. We suggest that conservation of the floristic diversity in Chandra Tal and Suraj Tal requires a proper conservation strategy, an effective tourism plan, regulation to prevent overgrazing, and species-specific conservation plans. Strict regulation with the aim to rotate grazing areas may be especially helpful in

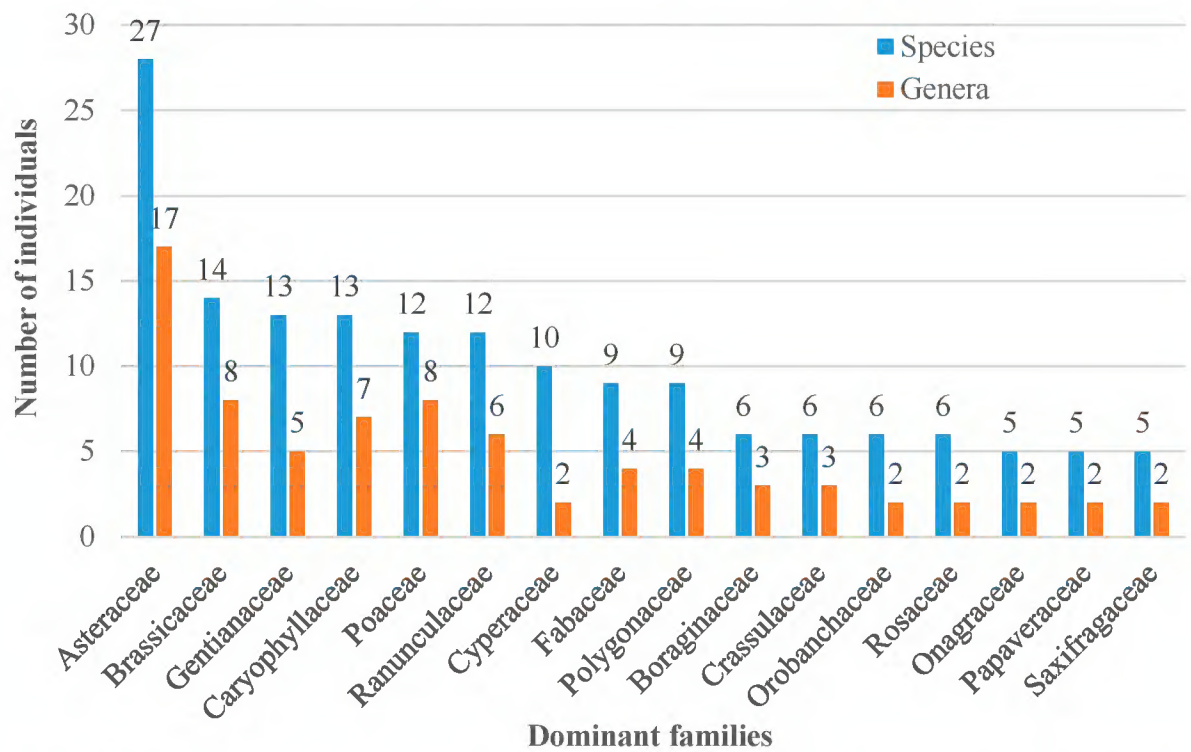


Figure 7. Dominant families with numbers of species and genera in and around Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti.

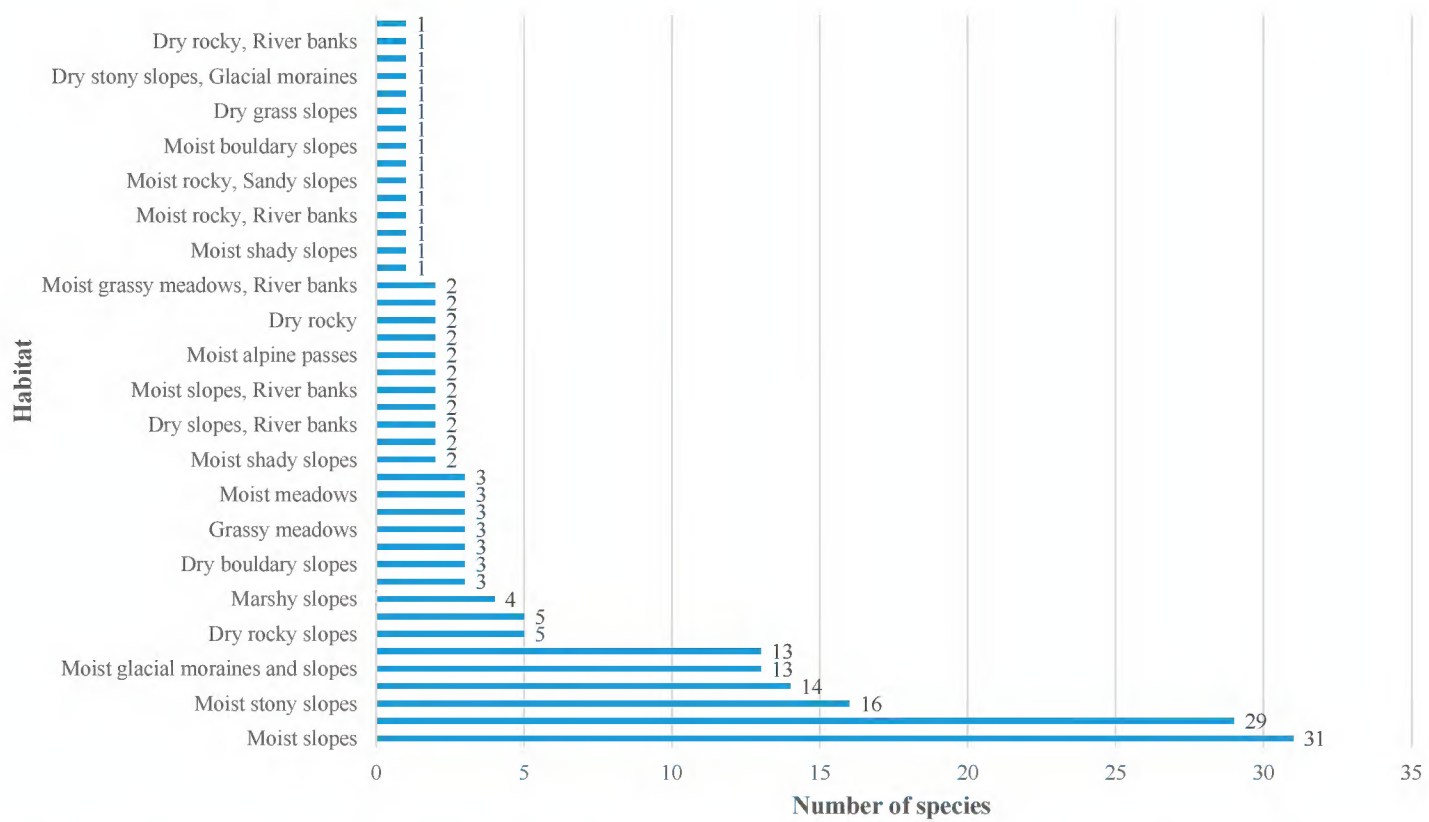


Figure 8. Distribution of species among different habitats in and around Chandra Tal and Suraj Tal high-altitude wetlands of Lahaul-Spiti.

maintaining habitat, as would be limiting tourists during peak months. The local communities should be involved in the management and conservation of high-altitude wetlands because their economies are highly dependent on these wetlands. Their traditional knowledge should also be incorporated into the conservation work to improve the wetlands ecology and their economy. Local people management committees can help regulate tourism-related activities, such as waste management, and also serve to guide tourists. The success of any conservation initiative will depend on the actions and cooperation of the forest department, local government administration, and the local communities.

Our findings should be of use to botanists, naturalists, conservationists, and policy makers in understanding the floristic diversity of two high-altitude wetlands in Lahaul-Spiti. Our study will also provide baseline data for further quantitative as well as qualitative investigations of valuable plants.

Acknowledgements

We are grateful to Er. Kireet Kumar (Director-in-Charge) and Dr. R.S. Rawal and Dr. P.P. Dhyani (Former Directors) of the G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora or providing necessary facilities and support. We acknowledge the research support received from Ministry of Environment, Forest and Climate Change (ER Division: 14/178/2013-ERS/RE). We are thankful to Principal Chief Conservator of Forest/Chief Wildlife Warden, Himachal Pradesh (WL/Research-study/WLM/1306–09) for providing necessary permission and Divisional Forest Officer, Lahaul-Spiti, for field guidance. We are thankful to Mr. Deepak Singh Negi for field assistance and the local people of Lahaul-Spiti for field guidance, local help, and logistic support. We are also grateful to the anonymous reviewers for providing valuable comments on the manuscript.

Authors' Contributions

DD: Conceptualization, Data curation, Formal analysis; PB: Methodology, Validation; KCS: Funding acquisition, Project administration; DA: Supervision.

References

- Anonymous (2009) National wetland conservation programme guidelines for conservation and management of wetlands in India. Conservation and Survey Division, Ministry of Environment and Forests, Government of India, New Delhi, India, 1–45.
- Anonymous (2010) Wetlands (Conservation and Management) Rules – 2010. Gazette of India, Part II, Section 3 (ii), Government of India, 1–8.
- Aswal BS, Mehrotra BN (1994) Flora of Lahaul-Spiti (a cold desert in north west Himalaya). Bishen Singh Mahendra Pal Singh, Dehradun, India, 761 pp.
- Bhattacharyya UC, Uniyal BP (1982) A botanical tour to Pangi and Trilokinath in upper Chenab. *Journal of Bombay Natural History Society* 79: 57–78.
- Brun F, Berthier E, Wagnon P, Käab A, Treichler D (2017) A spatially resolved estimate of High Mountain Asia glacier mass balances from 2000 to 2016. *Nature Geoscience* 10 (9): 668–673. <https://doi.org/10.1038/ngeo2999>
- Chandra Sekar K, Srivastava SK (2009) Flora of the Pin Valley National Park, Himachal Pradesh. Botanical Survey of India, Kolkata, India, 296 pp.
- Chandra Sekar K, Rawat B (2011) Diversity, utilization and conservation of ethnomedicinal plants in Devikund – a high altitude, sacred wetland of Indian Himalaya. *Medicinal Plants* 3 (2): 105–112. <https://doi.org/10.5958/j.0975-4261.3.2.017>
- Chase MW, Christenhusz MJM, Fay MF, Byng JW, Judd WS, Soltis DE, Mabberley DJ, Sennikov AN, Soltis PS, Stevens PF (2016) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society* 181 (1): 1–20. <https://doi.org/10.1111/boj.12385>
- Chowdhery HJ, Wadhwa BM (1984) Flora of Himachal Pradesh: Analysis. Botanical Survey of India, Calcutta, India, 860 pp.
- Dhar U, Samant SS (1993) Endemic plant diversity in Indian Himalaya I. Ranunculaceae and Paeoniaceae. *Journal of Biogeography* 20: 659–668. <https://doi.org/10.2307/2845521>
- IUCN (2021) The IUCN Red List of threatened species, version 2021-1. IUCN Red List Unit, Cambridge, UK. <https://www.iucnredlist.org>. Accessed on: 2021-2-9.
- Jain SK, Rao RR (1977) A handbook of field and herbarium methods. Today & Tomorrow's Printers and Publishers, New Delhi, India, 157 pp.
- Joshi AC (2003) Aquatic vegetation of Lahaul. *The Paleobotanist* 1: 277–280.
- Kala CP (2003) Medicinal plants of Indian Trans-Himalaya: focus on Tibetan use of medicinal resources. Bishen Singh Mahendra Pal Singh, Dehradun, India, 200 pp.
- Kala CP (2006) Medicinal plants of the high-altitude cold desert in India: diversity, distribution and traditional uses. *The International Journal of Biodiversity Science and Management* 2 (1): 43–56. <https://doi.org/10.1080/17451590609618098>
- Kapahi BK, Sarin YK (1979) Contribution of the botany of Lahaul. *Journal of Bombay Natural History Society* 74: 627–639.
- Koelz WN (1979) Notes on the ethnobotany of Lahul, a province of the Punjab. *Quarterly Journal of Crude Drug Research* 17 (1): 1–56. <https://doi.org/10.3109/13880207909083272>
- Mehta P, Chandra Sekar K, Bhatt D, Tewari A, Bisht K, Upadhyay S, Negi VS, Soragi B (2020) Conservation and prioritization of threatened plants in Indian Himalayan Region. *Biodiversity and Conservation* 29 (6): 1723–1745. <https://doi.org/10.1007/s10531-020-01959-x>
- Murti SK (2001) Flora of cold deserts of Western Himalaya. Vol. 1. (Monocotyledons). Botanical survey of India, Calcutta, India, 452 pp.
- Nair NC (1964) On a botanical tour to Lahul and Spiti (Punjab Himalayas). *Nelumbo* 6 (2–4): 219–235.
- Negi R, Verma PK, Baig S, Chandra A, Naithani HB, Verma R, Kumar A (2019) Checklist of family Poaceae in Lahaul and Spiti district (Cold Desert), Himachal Pradesh, India. *Plant Science Today* 6 (2): 270–274. <https://doi.org/10.14719/pst.2019.6.2.500>
- POWO (2021) Plants of the world online. Royal Botanic Gardens, Kew, UK. <http://www.plantsoftheworldonline.org/>. Accessed on: 2021-11-12.
- Rana MS, Samant SS (2011) Diversity, indigenous uses and conservation status of medicinal plants in Manali wildlife sanctuary, North western Himalaya. *Indian Journal of Traditional Knowledge* 10 (3): 439–459. <https://doi.org/10.3923/ajbs.2014.151.157>
- Rawat GS, Adhikari BS (2005) Floristics and distribution of plant

- communities across moisture and topographic gradients in Tso Kar basin, Changthang plateau, eastern Ladakh. *Arctic, Antarctic, and Alpine Research* 37 (4): 539–544. [https://doi.org/10.1657/15230430\(2005\)037\[0539:fadope\]2.0.co;2](https://doi.org/10.1657/15230430(2005)037[0539:fadope]2.0.co;2)
- Rau MA (1960) On a collection of plants from Lahaul. *The Bulletin of Botanical Survey of India* 2 (1–2): 45–56.
- Samant SS, Dhar U, Palni LMS (1998) *Medicinal Plants of Indian Himalaya: Diversity Distribution Potential Values*. Gyanodaya Prakashan, Nainital, India, 163 pp.
- Samant SS, Palni LMS, Pandey S (2012) Cold Desert Biosphere Reserve-Trans Himalaya, India. In: Palni LMS, Rawal RS, Rai RK, Reddy SV (Eds.) *Compendium on Indian biosphere reserves: progression during two decades of conservation*. G. B. Pant National Institute of Himalayan Environment and Ministry of Environment, Forest and Climate Change New Delhi, India, 169–177.
- Samant, Pant S, Singh M, Lal M, Singh A, Sharma A, Bhandari S (2007) Medicinal plants in Himachal Pradesh, north western Himalaya, India. *The International Journal of Biodiversity Science and Management* 3 (4): 234–251. <https://doi.org/10.1080/17451590709618177>
- Sangewar CV (2012) Remote sensing applications to study Indian glaciers. *Geocarto International* 2 (3): 197–206. <https://doi.org/10.1080/10106049.2011.617841>
- Schmidt R, Psenner R (1992) Climate changes and anthropogenic impacts as causes for pH fluctuations in remote high Alpine lakes. *Documenta dell'Istituto Italiano di Idrobiologia* 32: 31–57.
- Sharma P, Samant SS (2016) Diversity of Pteridophytes in the surroundings and dam submergence areas of hydroelectric projects in Kullu district of Himachal Pradesh, Indian Himalaya. *Forestry Ideas* 22 (2): 127–136.
- Singh A, Lal M, Samant SS (2009) Diversity, indigenous uses and conservation prioritization of medicinal plants in Lahaul valley, proposed Cold Desert Biosphere Reserve, India. *International Journal of Biodiversity Science & Management* 5 (3): 132–154. <https://doi.org/10.1080/17451590903230249>
- Singh KN, Lal B, Singh RD, Todaria NP, Ahuja PS (2007) Species richness, distribution pattern and conservation status of higher plants in the Spiti cold desert of trans Himalaya, India. *The International Journal of Biodiversity Science and Management* 3 (4): 223–233. <https://doi.org/10.1080/17451590709618176>
- Singh P, Karthigeyan K, Lakshminarasimhan P, Dash SS (2015) *Endemic vascular plants of India*. Botanical Survey of India, Kolkata, India, 215 pp.
- Srivastava SK, Shukla AN (2015) *Flora of cold desert Western Himalaya, India*. Vol. 2. Botanical Survey of India, Kolkata, India, 571 pp.
- Ved DK, Kinhal GA, Ravikumar K, Prabhakaran V, Ghate U, Sankar V, Indresha JH (2003) Conservation assessment & management prioritisation of selected medicinal plants of Jammu & Kashmir, Himachal Pradesh & Uttaranchal. Proceeding of the workshop held at Shimla during 19–24 May, 2003. Foundation for Revitalisation of Local Health Traditions, 24 pp. Unpublished report.